

Solar Powered Reciprocating Pump

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Purpose of this Manual:- This article is a note or manual for mechanical engineer where work as rotating engineer or where concern to apply reciprocating pump into the system. Article contain how to select pump, performance analysis, power estimation, NPSH estimation and also to create or complete calculation sheet, datasheet and specification sheet as a part of detail engineering and purchasing activity.[1]

Abstract- In present days, people need more and more power for driving instruments. A solar based reciprocating pump is a pump, running on electricity on electricity generated by solar cell, available from collected sunlight as opposed to greed electricity or diesel run water pump.

Nowadays many types of pump are available such as, positive displacement pump, impulse pump, velocity pump, gravity pump, steam pump, valve less pump. A reciprocating pump is class of positive displacement pump, is used for variety of purpose such as, car washing, irrigation, color spraying, extraction of oil from bottom of the earth, large fountain, garden water pump, etc. If 50% of the diesel pump were replaced with solar PV pump set, diesel consumption could be reduced to the turn of about 225 billion liter/year.

A solar reciprocating pumping systems is believed to be applicable to many remote and domestic irrigations applications without access to electricity relaying diesel power and having insufficient wind for pumping and to be cost competitive, locally manufacturable alternative to photovoltaic. This system consists of solar collector, battery, motor, crankshaft, reciprocating pump, valve, and tank. [2]

Keeping this entire thing in mind we are proposing to design solar powered reciprocating pump.

Index Terms- Reciprocating Pump, Solar PV panel, Battery, Crankshaft, Rotating panel, ON/OFF Valve.

I. INTRODUCTION

Aim:

It start from scratch with a definite mission, generates activities involving a variety of movement and human resources all direct towards fulfillment.

A project is a short time limited, goal directed, major undertaking, required the commitment of various skills and resources. It also describe goal together in a temporary organization to specific purpose. In project work, they have to make any machine or structure which is based on mechanical principal.

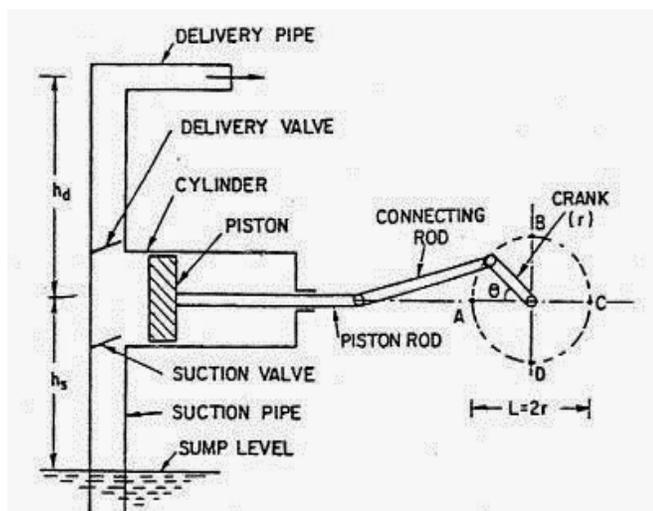
Type and construction features of reciprocating pump :

1. Position
 - Vertical
 - Horizontal
2. Purpose
 - Metering Pump
 - Power Pump
3. Piston or Plunger acting : Single acting, Double acting
4. Number of Plunger in One Casing : Single, Duplex, Triplex, Multiplex
5. Liquid End Type : Direct exposed, Diaphragm
6. Plunger direction : Forward, Backward. [1]

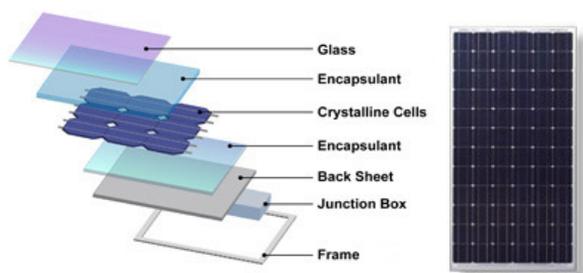
II. MAIN COMPONENTS OF SYSTEM

The Source: Water sources can be deep drilled wells, streams, springs, ponds, rivers, etc. The main variables, in addition to initial cost, that factor into system design are the recharge rate of the source and the volume of the source reservoir. Ideally, the source should recharge faster than pump can take water out of it. [3]

The pump: This is the heart and soul of the solar water pumping system. Pumps fall along a spectrum of high-flow/low-head to low-flow/high-head. In other words, for a given power input, the pump produces a unique combination of flow and pressure. When selecting a pump you are basically selecting that combination of performance characteristics. Solar pumps are rated according to the voltage of electricity that should be supplied. A 12 volt pump is a small one, 24 volt is more the norm, while 48 volts and upwards will require more power and might pump more water. These include filters, float valves, switches, etc.[3]



Photovoltaic (PV) panels: The photovoltaic panels make up most (up to 80%) of the systems cost. The size of the PV-system is directly dependent on the size of the pump, the amount of water that is required (m^3/d) and the solar irradiance available. A panel is rated in watts of power it can produce. The SPV water pumping system should be operated with PV array capacity in the range of 200 Watts peak to 5000 Watts peak, measured under Standard Test Conditions (STC). Sufficient number of modules in series and parallel could be used to obtain the required PV array power output. The power output of individual pvModules used in the PV array, under STC, should be a minimum of 74 Watts peak, with adequate provision for measurement tolerances. Use of PV modules with higher power output is preferred. Indigenously produced PV module(s) containing mono/multicrystalline silicon solar cells. [3]



The water distribution system:- In many countries of the world, trenches are dug to gravity feed water through an intricate network of irrigated plots or holding tanks. Here farmers tend to use black polyethylene piping. Whatever the system is to get water, there important thing to consider is the smaller the diameter piping and the longer the piping run, the harder a pump has to work and the more pressure the pump must create. [3]

Motor pump-set: Following types of motor pump sets could be used in the SPV water pumping systems

- 1 Surface mounted DC motor pump-set
- 2 Submersible DC motor pump set
- 3 Submersible AC motor pump set
- 4 Floating DC motor pump set.

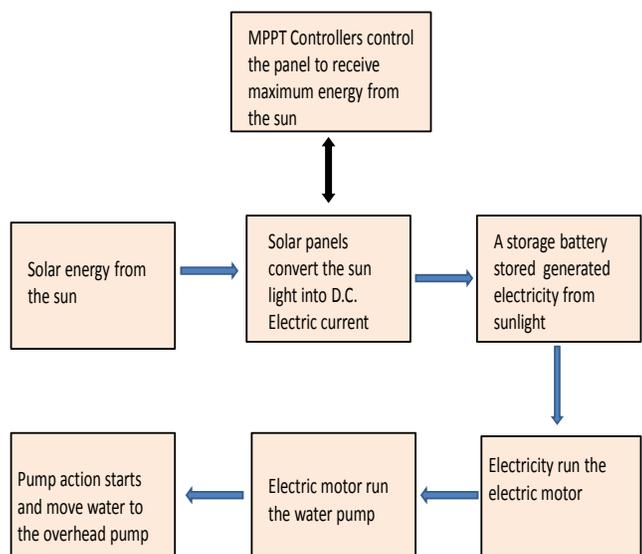
Mounting structures and tracking system: To enhance the performance of SPV water pumping systems, it is desirable to use a tracking system. Manual, passive and auto tracking are permitted. The PV modules will be mounted on metallic structures of adequate strength and appropriate design, which can withstand load of modules and high wind velocities up to 150 km per hour. The support structure used in the pumping system will be hot dip Galvanized iron (G.I). The G.I. structures for mounting the Solar panels could be so designed, that these can be manually/ auto adjusted for optimal tilt throughout the year.6. Controller: The purpose of the controller is twofold. Firstly, it matches the output power that the pump receives with the input power available from the solar panels. Secondly, a controller usually provides a low voltage protection, whereby the system is switched off, if the voltage is too low or too high for the operating voltage range of the pump. This increases the lifetime of the pump thus reducing the need for maintenance. [4]

Inverter:- It changes the direct current from the solar panels into alternating current for the pump. The supported power range of inverters extends from 0.15 to 55 kW and can be used for larger irrigation systems. However, the panel and inverters must be sized accordingly to accommodate the inrush characteristic of an AC motor. [5]

| SR. NO. | COMPONENTS | MATERIAL |
|---------|--------------------|-----------------|
| 1 | Solar panel | Silicon |
| 2 | Battery | - |
| 3 | Crank shaft | Mild Steel |
| 4 | Motor | - |
| 5 | Valve | Stainless Steel |
| 6 | Tank | Mild Steel |
| 7 | RECIPROCATING PUMP | Plastic |
| 8 | Pipe | Stainless Steel |
| 9 | Stand | Mild Steel |

Working:-

Working principle:



Solar pumps utilize the photovoltaic effect to produce free electricity used for water pumping. Photons of light hit a collection of solar cell, exciting electrons into a higher state of energy, making them act as charge carriers an electric current. This is how Photovoltaic (PV) cells produce electricity. DC electricity is produced in a set of silicon solar cells gathered in modules and put together into arrays. Connected to a

reciprocating pump. Inlet pipe of reciprocating pumps are mounted or in the source and its outlet to the water delivery point. Storage can be done by the use of elevated water tanks or storage ponds where water is stored until it is demanded and delivered to end-users or through the use of batteries that store electricity and save it until there is demand for water. The first is apparently more feasible and less maintenance-demanding as compared to battery storage systems. [6]

Some solar pumping applications use tracking systems to maximize power production and increase daily gain, through single axis or dual axis tracking solar collectors. This is applied in case of high volume demand but requires large water storage volumes.

Most commercial HPLC pumps are based on a reciprocating piston design, as shown here. A motor-driven cam pulls the piston back and forth in the pump head. A flexible seal around the periphery of the piston prevents leakage of mobile phase out the back of the pump. Check valves mounted in the head open and close in response to small changes in pressure to maintain a one-way flow of solvent.

The pump cylinder with its check valves is often accessible from the outside to allow easier servicing of the check valves and replacement of the pump seals. This part of the pump is called the pump head. During the delivery stroke, flow increases from zero up to a maximum, then decreases back to zero. During the intake stroke, flow is zero. The pressure inside the pump changes in the same way as flow going from zero to a maximum value, and then staying at zero during the intake stroke.[7]

Methodology:-

Lathe Machine:-

Grinding machine:-

| | |
|---------------------------|----------------|
| Height from centre length | 165mm |
| Length | 1829mm |
| Swing over saddle | 203mm |
| No. of spindle possible | 8 |
| Range of spindle speed | 240-750 rpm |
| Range of cross feed | 0.008-0.0223mm |
| Net weight of machine | 690 kg |

Drilling machine:-

| | |
|---------------------------|----------------|
| Height from centre length | 165mm |
| Length | 1829mm |
| Swing over saddle | 203mm |
| No. of spindle possible | 8 |
| Range of spindle speed | 240-750 rpm |
| Range of cross feed | 0.008-0.0223mm |
| Net weight of machine | 690 kg |

Cutter machine:-

| | |
|---------------------------|--------|
| Height from centre length | 165mm |
| Length | 1829mm |

| | |
|-------------------------|----------------|
| Swing over saddle | 203mm |
| No. of spindle possible | 8 |
| Range of spindle speed | 240-750 rpm |
| Range of cross feed | 0.008-0.0223mm |
| Net weight of machine | 690 kg |

Welding machine:-

| | |
|--------------------------|----------|
| Types of welding machine | Electric |
| Power required | 3 Phase |
| Height | 760 mm |
| Length | 900 mm |

Important Parameters:-

[9]

• Displacement (gpm) is the calculated capacity of the pump with no slip losses. For single-acting plunger or piston pumps, it is defined as the following:

Where: D = displacement, (gpm US)

A = cross-sectional area of plunger or piston, (in²)

M = number of plungers or pistons

n = speed of pump, (rpm)

s = stroke of pump, (in.) (half the linear distance the plunger or piston moves linearly in one revolution)

f) Slip(s)

• Slip is the capacity loss as a fraction or percentage of the suction capacity. It consists of stuffing box loss BL plus valve loss VL. However, stuffing box loss is usually considered negligible.

g) Valve Loss (VL)

• Valve loss is the flow of liquid going back through the valve while it is closing and/or seated. This is a 2% to 10% loss depending on the valve design or condition.

h) Speed (n)

• Design speed of a power pump is usually between 300 to 800 rpm depending on the capacity, size, and horsepower.

To maintain good packing life, speed is limited to a plunger velocity of 140 to 150 ft/minute. Pump speed is also limited by valve life and allowable suction conditions.

i) Pulsations

• The pulsating characteristics of the output of a power pump are extremely important in pump application. The magnitude of the discharge pulsation is mostly affected by the number of plungers or pistons on the crankshaft.

j) Net Positive Suction Head Required (NPSHR)

• The NPSHR is the head of clean clear liquid required at the suction centerline to ensure proper pump suction operating conditions. For any given plunger size, rotating speed, pumping capacity, and pressure, there is a specific value of NPSHR. A change in one or more of these variables changes the NPSHR.

• It is a good practice to have the NPSHA (available) 3 to 5 psi greater than the NPSHR. This will prevent release of vapour

and entrained gases into the suction system, which will cause cavitations damage in the internal passages.

k) Net Positive Suction Head Available (NPSHA)

• The NPSHA is the static head plus the atmospheric head minus lift loss, frictional loss, vapour pressure, velocity head, and acceleration loss in feet available at the suction centre-line

Installation, Operation, and Troubleshooting of Pumps

• The subsequent data will provide useful to personnel involved in the application or maintenance of pumps. The information is categorized into the following headings:

I. Alignment of Shafts

II. Water Hammer

I. ALIGNMENT OF SHAFTS

Misalignment of the pump and driver shaft can be angular (shaft axes concentric but not parallel), parallel (shaft axes parallel but not concentric), or a combination of both

a. COUPLINGS

• Couplings provide a mechanically flexible connection for two shaft ends that are in line.

• Couplings also provide limited shaft end float (for mechanical movement or thermal expansion) and within specified limits, angular and parallel misalignment of shafts.

Couplings are not intended to compensate for major angular or parallel misalignment.

• The allowable misalignment will vary with the type of coupling, and reference should be made to the manufacturer's specifications enclosed with the coupling. Any improvement in alignment over the coupling-manufacturer's minimum specification will increase pump, coupling, and prime mover life by reducing bearing loads and wear.

• Flexible couplings in common use today are chain, gear, steel grid, and flex member.

b. Angular Misalignment

• To check angular misalignment

- insert a feeler gauge between the coupling halves to check the gap;

- check the gap between coupling halves at the same location on the coupling as for the original gap check.

- To correct angular misalignment, adjust the amount of shims under the driver and/or adjust driver location in the horizontal plane.

c. Parallel Misalignment

- To check parallel misalignment, the dial indicator method is used
 - with the dial indicator attached to the pump or driver shaft, rotate both shafts simultaneously, and record dial indicator readings through one complete revolution;
 - correct the parallel misalignment by adjusting shims under the driver.
- On certain large units, limited end float couplings are used.

III. WATER HAMMER

Water hammer is an increase in pressure due to rapid changes in the velocity of a liquid flowing through a pipeline. This dynamic pressure change is the result of the transformation of the kinetic energy of the moving mass of liquid into pressure energy. When the velocity is changed by closing a valve or by some other means, the magnitude of the pressure produced is frequently much greater than the static pressure on the line, and may cause rupture or damage to the pump, piping, or fittings. This applies both to horizontal and vertical pump installations.

The velocity of the pressure wave depends upon the ratio of the wall thickness to the inside pipe diameter, on the modulus of elasticity of the pipe material, and on the modulus of Elasticity of the liquid.

The head due to water hammer in excess of normal static head is a function of the destroyed velocity, the time of closure, and the velocity of pressure wave along the pipe.

Benefits of solar water reciprocating pump:

- Solar water pumps are used for irrigation of crops, water livestock and provide portable drinking water.
- Solar water pump uses peak solar array output which frequently coincides with high-water demand during long, dry summer days.
- Solar water pumps can also be designed for portability to be moved based on water demand or change of season requires.
- Their operating cost is less compared to diesel pumps.
- Recent fuel price increases and generally intensive maintenance schedules however can make diesel pumps expensive.[8]

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